STORAGE AND SHELF LIFE OF PACKAGED WATERCRESS, PARSLEY, AND MINT

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ABSTRACT

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Storage and shelf-life tests were conducted with watercress, parsley, and mint grown in Ohio, Pennsylvania, and Florida. The vegetables were trucked under container and top ice to the Washington, D.C., area, where they were purchased the day after harvest and hauled to Beltsville, Md., for testing.

In packaging tests before storage, watercress and mint held up well at 0° C and 95 percent relative humidity for up to 4 weeks in perforated polyethylene bags but only 4 days in naked bunches, whereas at 20° and 60 percent relative humidity they held up for only 2 and 4 days, respectively, in polyethylene bags and 1 day or less in naked bunches.

In limited storage tests using container and top ice, watercress and parsley held up well for 2 to 3 weeks and mint for 2 weeks at 0° C.

After crate storage and subsequent packaging in polyethylene bags, the bunches of parsley remained salable at 0° C for 21 to 36 days beyond 4 weeks' storage and up to 14 days beyond 8 weeks' storage. At 10°, bunches in polyethylene remained salable for 4 to 6 days beyond the 4 and 8 weeks' storage. Parsley bunches packaged after 0° storage in cartons or crates with container and top ice had longer shelf life than bunches from containers stored dry without ice.

Data are included on weight loss and wilt for the three greens. Respiration rates were highest for parsley, next for watercress, and lowest for mint. Initial reduced ascorbic acid content was about 48, 93, and 34 mg per 100 grams, respectively, for watercress, parsley, and mint. Reduced ascorbic acid content of parsley dropped during storage and shelf life. Higher losses of ascorbic acid were associated with higher holding temperatures and higher weight, turgor, and general appearance losses.

KEYWORDS: Watercress, parsley, mint, packaging, storage, shelf life.

On January 24, 1978, four USDA agencies--Agricultural Research Service (ARS), Cooperative State Research Service (CSRS), Extension Service (ES), and the National Agricultural Library (NAL)--merged to become a new organization, the Science and Education Administration (SEA), U.S. Department of Agriculture.

This publication was prepared by the Science and Education Administration's Agricultural Research staff, which was formerly the Agricultural Research Service.

PREFACE

U.S. Department of Agriculture marketing research is part of a continuing program to reduce marketing losses and to extend the marketing season of agricultural products. This study was undertaken to find improved methods for handling and packaging watercress, parsley, and mint and to determine their storage requirements and shelf life.

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STORAGE AND SHELF LIFE OF PACKAGED WATERCRESS, PARSLEY, AND MINT

By Howard W. Hruschka and Chien Yi Wang[1/]

BACKGROUND

In the United States, estimated planting and annual commercial production of watercress, parsley, and mint for fresh consumption are as follows:

	Hectares	Metric tons
Watercress	120	2,300
Parsley, leaf	1,000	27,300
Mint	800	22,700

About 4,044 hectares of mint were used for oil in 1976 (24).[2/]

Recommended storage conditions for leafy green vegetables are reported as about 0° C and 90 to 95 percent relative humidity (16). Container and top ice and film liners for storage and shipping containers are also recommended to help maintain low temperature and high humidity around the produce. Under these conditions, parsley is reported to keep well for 1 to 2 months (13) and watercress for 3 to 4 days (22), with no mention of mint. Average, lowest, and highest freezing points for leaves and petioles of parsley are given as -1.28°, -1.33°, and -1.11°, respectively (26), with no data for watercress or mint. Elsewhere, -2.5° to -3.5° were found to give best results and to hold parsley for 11 weeks (18). It was reported to keep well for 17 days at 0°, 7 days at 5°, and 3 days at 10° (14); -2° and -3° were injurious.

Initial respiration rates in milligrams of carbon dioxide per kilogram per hour at 0°, 5°, 10°, and 12.5° C, respectively, were approximately 40, 60, 100, and 140, with keeping time for parsley concluded as 3 to 4 months at 0° to -1° and possibly 1 month more in modified atmosphere (2). Reduction in volatile aromatics, ascorbic acid, and carotin in parsley was associated with fading and withering at room temperature (21).

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2/ Underlined numbers in parentheses refer to Literature Cited at the end of this report.

Nutrient components as international units of vitamin A and milligrams of ascorbic acid (vitamin C) per 100 grams of fresh weight are given as follows:

	IU	Mg
Watercress	4,900	79
Parsley	8,500	172
Peppermint	15,000	36
Spearmint	11,000	76

Source: Items 1-2 (25); items 3-4 (unpub. notes, Anne C. Marsh, Sci. and Educ. Admin.).

Additional information on culture and handling of watercress and parsley for food and notes on mint, mainly for oil production, are given in several publications (1, 4, 5, 15, 17, 19, 20, 23).

The study reported here was conducted to find improved methods for handling, storing, and packaging fresh watercress, parsley, and mint and to determine their storage requirements and shelf life under various holding conditions. Reports of similar research on other commodities are available (6, 7, 9, 10, 11, 12, 16).

MATERIALS AND METHODS

Storage and shelf-life tests of fresh watercress, parsley, and mint were conducted at Beltsville, Md., from June 1977 to January 1978 using 7 twelve-bunch cartons of watercress, 20 sixty-bunch crates or crate equivalents of parsley, and 7 twelve-bunch cartons of mint. Within each carton or crate the consumer-unit bunches were each secured by a rubberband.

The watercress used was an unnamed selection of *Nasturtium officinale* R. Br., the parsley was *Petroselinum crispum* (Mill.) Nym. ex A. W. Hill cv. Emerald (curled parsley), and the mint was a selection of *Mentha spicata* X *M. aquatica* var. *crispa* (L.) Benth. [*M. crispa* L.] (curled mint). The greens were grown in Ohio, Pennsylvania, and Florida. They were trucked to the Washington, D.C., area under container and top ice plus mechanical refrigeration, and testing was begun at Beltsville, Md., on the day following harvest.

During transit and storage, watercress was held in waxed cartons measuring outside 23 by 21-1/2 by 23 cm and inside 22-1/2 by 21 by 22-1/2 cm. Parsley was held in 1-bushel wirebound wood crates measuring outside 42-1/2 by 30-1/2 by 30-1/2 cm and inside 38-1/2 by 29-1/2 by 29-1/2 cm, in 1-1/9-bushel crates measuring 5-1/4 cm longer than the 1-bushel crates, and in overhandle wood splint (veneer) market baskets measuring inside 43 by 20 by 15 cm, each fitted with a thin-wood veneer lid and holding 24 bunches. Mint was held in waxed cartons measuring outside 31 by 16 by 24-1/2 cm and inside 30 by 15-1/2 by 24 cm.

During storage, containers were either nonlined or had a 1.5-mil perforated polyethylene film liner and were held at 0° C with or without container and top ice. Also bunches of watercress, parsley, and mint, each secured by a rubberband, were held either naked (nonwrapped) or placed in a

perforated (4- to 0.5-cm holes) polyethylene bag with a twist-tie closure.

Following a preliminary quality survey of parsley from nearby supermarkets, tests of the three leafy greens were conducted in three phases: Initial consumer-unit holding test, initial crate-carton storage test, and poststorage consumer-unit holding tests. Temperatures of 0°, 5°, 10°, 15°, 20°, and 25° C were used to test storage and shelf life, respiration rates, and changes in reduced ascorbic acid (vitamin C) content of the three leafy greens. Accompanying relative humidities were 95 percent for 0°, 5°, and 10° rooms and 75, 60, and 40 percent, respectively, for 15°, 20°, and 25° rooms. Other details of materials and methods are given under individual tests.

Generally tests were set up in split-plot experimental design. Where appropriate, the data were processed by analysis of variance and by Duncan's multiple range test at the 5-percent level of significance (8).

PRELIMINARY OBSERVATIONS

Store Survey

Forty bunches of parsley sampled on 2 dates at 10 supermarkets near Beltsville, Md., weighed from 36 to 138 grams each. Retail price per bunch on both days was 27 to 33 cents and unit price 22 to 79 cents per 100 grams as purchased. Overall cost of the edible portion ranged from 23 cents to $1.45 per 100 grams. All parsley seen was offered for sale as naked bunches, each secured by a rubberband.

In general appearance evaluations in the 10 stores, 10 bunches of parsley were rated excellent, 8 good, 9 fair, 8 poor, and 5 very poor. After trimming the 40 bunches of 4 to 67 percent of blemished leaves, 19 bunches were rated excellent, 11 good, 5 fair, and 5 poor.

Reduced ascorbic acid (vitamin C) content using AOAC methods (3) averaged 70 (23-141) mg per 100 grams of fresh weight of parsley. Turgid, less turgid to trace limp, and limp parsley, respectively, averaged 77, 67, and 41 mg of ascorbic acid per 100 grams. Parsley rating excellent, good to fair, and poor to very poor in general appearance, respectively, averaged 76, 69, and 66 mg of ascorbic acid per 100 grams.

Weight Loss and Wilt

Weight loss and wilt severity were determined for 20 single stalks of parsley held at 25° C and 40 percent relative humidity and for 12 bunches each of watercress, parsley, and mint held in 6 rooms at 0°, 5°, 10°, 15°, 20°, 25° with relative humidities of 95 to 40 percent. Weight loss data from the six rooms were combined for each of the three bunched vegetables (table 1). As in other weight loss tests (10), each item, stalk, or bunch was initially weighed, then placed and held for subsequent weighing in a single layer well separated from adjacent items. Subsequent weighings were at frequent intervals to estimate maximum weight lost before any symptom was evident (zero) and minimum weight loss associated with onset at each degree of wilt (trace, slight, moderate, severe, and extremely severe).

Table 1.--Weight loss at onset of wilt symptoms in bunches of watercress, parsley, and mint held naked at 0° to 25° C and 95 to 40 percent relative humidity[1/]

Wilt symptom	Weight loss of--		
	Watercress	Parsley	Mint
	Percent	Percent	Percent
Zero	9.6 (7-11) a	9.6 (6-13) a	10.4 (9-13) a
Trace	15.4 (9-20) ab	20.5 (9-25) b	17.8 (15-21) b
Slight	22.5 (15-30) b	30.5 (13-38) c	27.1 (22-35) c
Moderate	39.9 (28-68) c	42.1 (30-50) d	40.3 (34-49) d
Severe	60.7 (46-74) d	61.4 (43-75) e	63.0 (47-74) e
Extremely severe	85.8 (80-89) e	87.4 (84-90) f	80.8 (70-89) f

1/ Averages and ranges (in parentheses) are based on 12 bunches each of watercress, parsley, and mint, 2 from each of 6 temperature holding rooms. Data are maximum weight losses at which no symptoms could be detected (zero) and minimum losses at onset of each symptom (trace to extremely severe). Duncan's multiple range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (8).

Trace and slight wilt did not affect commercial appearance. Moderate, severe, and extremely severe wilt progressively downgraded appearance. As for other vegetables and fruits (10), weight losses associated with the various symptoms were higher than expected. Before trace symptoms appeared, 6 to 13 percent weight had been lost. When moderate or commercially significant symptoms were seen, 28 to 68 percent weight had been lost. Averages and ranges for single stalks of parsley (not shown in table 1) were similar to those reported for bunched parsley.

Respiration Rates

Respiration as carbon dioxide produced by each vegetable at six temperatures was measured with a Fisher gas partitioner model 29 for watercress, parsley, and mint on arrival at Beltsville on the day after harvest and in addition for parsley after 4 and 8 weeks' storage at 0° C under top ice (table 2). In general, parsley respired most rapidly and mint least rapidly, with watercress intermediate. Exceptions occurred at 20° and 25°, with watercress respiring more rapidly than parsley or mint. Respiration rates for parsley consistently decreased with storage time at 0°.

Ascorbic Acid Content

Ascorbic acid (vitamin C) content as milligrams of reduced ascorbic acid per 100 grams fresh weight was determined for watercress, parsley, and mint using AOAC methods (3) on the day after harvest and subsequently for parsley after various storage and holding times and conditions. On arrival at Beltsville, ascorbic acid content per 100 grams in six replicate samples each averaged 48.1 (44-52) mg in watercress, 92.6 (85-102) mg in parsley, and 33.9 (31-36) mg in mint. In nine replicate samples of parsley for each determination before and after 4 and 8 weeks' storage in crates with container and top ice, ascorbic acid content per 100 grams averaged 91.3 (74-103), 62.0 (58-69), and 36.1 (30-45) mg, respectively. In holding tests with parsley at six temperatures, significantly more ascorbic acid was retained in polyethylene-bagged than in naked bunches and at lower than at higher temperatures (table 3). Generally more ascorbic acid was present before than after holding parsley 1 or 3 days. Most ascorbic acid was lost from parsley that lost most weight and deteriorated most in general appearance (table 4) (21).

STORAGE AND SHELF-LIFE TESTS

Initial Consumer-Unit Holding Test

Test 1.--Watercress, parsley, and mint held in air after packaging in consumer-unit polyethylene bags 1 day after harvest

Two replicate bunches each of watercress, parsley, and mint were held naked (nonwrapped) or each enclosed in a perforated (4- to 0.5-cm holes) polyethylene (1.5 mil) bag in storage rooms maintained at 0°, 5°, 10°, 15°, 20°, and 25° C with relative humidities of 95, 95, 95, 75, 60, and 40 percent, respectively. They were observed daily until they deteriorated to unsalable condition (tables 5 and 6).

Table 2.--Respiration rates as carbon dioxide produced by fresh watercress, parsley, and mint at 6 temperatures and various times after harvest[1/]

Holding temperature (°C)	Carbon dioxide at indicated time after harvest per kilogram of--				
	Watercress at 1 day	Parsley at--			Mint at 1 day
		1 day	4 weeks at 0° C	8 weeks at 0° C	
	Mg/h	Mg/h	Mg/h	Mg/h	Mg/h
0----------	15	33-46	26-33	13-20	8-15
5----------	45	66-85	46-59	33-39	30
10----------	91-121	131-164	85-105	59-92	76-91
15----------	136-196	144-223	124-164	92-124	105-136
20----------	302-348	196-255	170-223	124-164	166-227
25----------	348-438	308-341	275-308	176-248	257-317

1/ Each range is based on readings 1 day after harvest of 4 samples of each vegetable and 4 and 8 weeks after harvest of 6 samples of parsley. In converting respiration rates to British thermal units (Btu) or megajoules (MJ), multiply milligrams of carbon dioxide per kilogram of vegetable per hour by the factor 220 to get Btu's per ton per 24 hours (16) or by the factor 0.25586 to get MJ's per metric ton per 24 hours. 1 MJ per metric ton equals 1 joule per gram.

Table 3.--Reduced ascorbic acid (vitamin C) content of fresh parsley held naked or in perforated polyethylene bags for 1 and 3 days at 6 temperatures[1/]

Holding time and temperature (°C)	Reduced ascorbic acid of bunches held-- Naked	In polyethylene bags	Average
1 day	Mg/100 g	Mg/100 g	Mg/100 g
0	90.0 abc	93.8 a	91.9 a
5	94.2 a	91.5 ab	92.9 a
10	88.2 abcd	89.5 abcd	88.9 ab
15	77.5 def	85.8 abcde	81.6 b
20	66.0 gh	81.2 bcde	73.6 c
25	57.2 hi	75.2 efg	66.2 c
Average	78.9 b	86.2 a	82.52a
3 days			
0	85.0 abcde	89.8 abcd	87.4 ab
5	82.8 abcde	86.8 abcde	84.8 ab
10	65.2 gh	77.8 cdef	71.5 c
15	29.2 j	67.0 gh	48.1 d
20	19.2 jk	58.8 hi	39.0 e
25	11.5 k	48.5 i	30.0 f
Average	48.8 d	71.4 c	60.12 b
Average (both times)			
0	87.5 a	91.8 a	89.62a
5	88.5 a	89.1 a	88.81a
10	76.8 b	83.6 ab	80.19 b
15	53.4 d	76.4 b	64.88 c
20	42.6 e	70.0 b	56.31 d
25	34.4 f	61.9 c	48.12 e
Grand average--	63.85 b	78.79a	71.32

1/ Milligrams reduced ascorbic acid per 100 grams fresh weight of parsley = mg/100 g. When parsley was placed in holding rooms, initial reduced ascorbic acid content averaged 93.1 (85-102) mg per 100 grams. Each simple value within heavy lines is based on 4 replicate samples of parsley. Duncan's multiple range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (8).

Table 4.--Weight loss, general appearance, and ascorbic acid content of parsley held naked or in polyethylene bags for 1 and 3 days at 2 temperatures and 2 relative humidities[1/]

Holding time, temperature (C), and relative humidity (percent)	Held naked			Held in polyethylene bags		
	Weight loss	General appearance	Ascorbic acid	Weight loss	General appearance	Ascorbic acid
1 day	Percent	Rating	Mg/100 g	Percent	Rating	Mg/100 g
0° and 95----------	18	8	90	1	10	94
25° and 40----------	51	5	57	9	10	75
3 days						
0° and 95----------	33	5	85	2	10	90
25° and 40----------	79	2	12	20	5	48

1/ Milligrams ascorbic acid per 100 grams fresh weight of parsley = mg/100 g. Each value is based on 4 replicate samples of parsley. For description of ratings, see table 5.

Table 5.--Description of numerical ratings for condition traits[1/]

Condition trait	Rating description					
	10	8	6	4	2	0
Wilt----------	None-------	Trace---	Slight----	Moderate---	Severe---	Extremely severe.
Turgor----------	Turgid-----	Less turgid.	Trace limp.	Limp-------	Dried----	Brittle.
Yellow green----	Dark green.	Light green.	Slight yellow.	Moderate yellow.	Severe yellow.	Completely yellow.
Decay----------	None-------	Trace---	Slight----	Moderate---	Severe---	Extremely severe.
General appearance----	Excellent--	Good----	Fair------	Poor-------	Very poor.	Like garbage.

1/ The higher the numerical rating the better the condition.

Table 6.--Shelf life as days salable and daily weight loss of watercress, parsley, and mint held in air at various temperatures and relative humidities after packaging of consumer units in naked bunches or polyethylene bags 1 day after harvest[1/]

Holding temperature (C) and relative humidity (percent)	Watercress in--		Parsley in--		Mint in--	
	Naked bunches	Polyethylene bags	Naked bunches	Polyethylene bags	Naked bunches	Polyethylene bags
	Shelf life					
	Days	Days	Days	Days	Days	Days
0° and 95	4	28	1	>3	4	28
5° and 95	3	7	1	>3	2	10
10° and 95	3	4	1	>3	2	10
15° and 75	1	2	1	>3	<1	4
20° and 60	<1	2	1	>3	<1	4
25° and 40	<1	1	<1	1	<1	4
	Daily weight loss					
	Percent	Percent	Percent	Percent	Percent	Percent
0° and 95	3.2	.1	11.1	.7	6.1	.2
5° and 95	6.4	.5	10.4	.8	10.4	.5
10° and 95	8.1	.3	10.7	1.2	11.4	.4
15° and 75	12.3	.9	19.7	3.7	20.0	.6
20° and 60	18.9	1.4	16.1	2.3	22.9	1.1
25° and 40	20.3	1.8	26.4	6.7	26.2	2.2

1/ Each value is based on 2 bunches of green vegetable. <1 = less than 1, >3 = more than 3. In shelf tests, parsley was observed only after 1 and 3 days. See text under test 1 for more detail.

The leafy greens generally remained acceptable longer in polyethylene bags than in naked bunches and at lower temperatures with higher relative humidity than at higher temperatures with lower relative humidity. Thus, watercress and mint at 0° C and 95 percent relative humidity remained acceptable for 4 weeks in polyethylene bags and 4 days in naked bunches. At 15° and 75 percent relative humidity, watercress was acceptable for 2 days in polyethylene bags and 1 day in naked bunches, whereas mint was acceptable for 4 days in polyethylene bags and less than 1 day in naked bunches. In this test parsley was observed only after 1 and 3 days' holding. Nonetheless at 0°, parsley remained fresh in polyethylene bags for at least 3 days, whereas in naked bunches it was unsalable at 3 days due to loss of weight and turgor. And at 25°, parsley kept as well as watercress, being salable after 1 day in polyethylene and less than 1 day in naked bunches.

Causes of deterioration in watercress, parsley, and mint were yellowing and decay in polyethylene bagged bunches, and mainly wilting due to excessive weight loss (table 6) in naked bunches. Weight loss per day of the three vegetables ranged from less than 1 percent in bunches in polyethylene bags held at 0° C and 95 percent relative humidity to more than 20 percent in naked bunches held at 25° and 40 percent relative humidity.

Initial Crate-Carton Storage Test

Test 2.--Storage life of watercress, parsley, and mint in shipping and storage containers with container and top ice at 0° C

Two replicate storage and shipping containers each of watercress, parsley, and mint were placed in 0° C storage with container and top ice the day after harvest. The watercress and mint bunches were each packed 12 bunches per waxed carton and the parsley was packed 24 bunches per overhandle wood splint (veneer) market basket with a wood veneer lid. Bunches of the three greens were rated for condition traits before storage and after 1, 2, 3, and 4 weeks' storage or until the container of greens became nonsalable (table 7).

Containers of watercress and parsley held up well for 2 to 3 weeks and were nonsalable at 4 weeks. Containers of mint held up well for 2 weeks and were nonsalable at 3 weeks. As they became nonsalable, one container of each of the greens was salvaged by washing and trimming to yield 60 percent salable watercress, 45 percent salable parsley, and 25 percent salable mint.

Poststorage Consumer-Unit Holding Tests

Test 3.--Parsley held in air at 0°, 10°, and 20° C after packaging in consumer-unit polyethylene bags following 2, 4, and 8 weeks' storage at 0°

Twelve wirebound wood bushel crates of bunched parsley were purchased at a Washington, D.C., wholesale market and placed in a storage and shelf-life test at Beltsville the day after harvest in September 1977. Sample bunches were immediately placed in a consumer-packaging shelf-life test at 0°, 10°, and 20° C and enough of the remainder was used to pack two waxed cartons, four polyethylene-lined wirebound wood crates, and four nonlined wirebound wood

Table 7.--Condition rating at 0-4 weeks' storage of watercress, parsley, and mint freshly harvested 1 day before storing in 12-bunch waxed cartons or in 24-bunch overhandle splint market baskets with container and top ice at 0° C[1/]

Storage time (weeks)	Wilt turgor	Yellow green	Decay	General appearance	Salable
	Rating	Rating	Rating	Rating	
		Watercress in 12-bunch cartons			
0	10	10	10	10	Yes.
1	10	10	10	10	Do.
2	10	10	10	10	Do.
3	10	10	7	6	Barely.
4	10	9	4	4	No.
		Parsley in 24-bunch baskets			
0	10	9	10	9.5	Yes.
1	10	9	10	9.5	Do.
2	10	9	10	9.5	Do.
3	10	9	7.5	7.5	Barely.
4	10	9	5	5	No.
		Mint in 12-bunch cartons			
0	10	10	10	10	Yes.
1	10	10	10	9.8	Do.
2	10	10	9	9	Do.
3	10	10	2.5	2.5	No.

1/ Each value is based on observations of a total of 24 bunches, 12 from each of 2 replicate shipping and storage containers. For description of ratings, see table 5.

crates. Half the number of each type of container was supplied with container ice and placed at 0° under top ice and the other five containers were placed at 0° without ice (dry).

Observations were made and sample bunches were removed from each of the 10 containers after 2, 4, and 8 weeks' storage at 0° C for shelf-life tests at 0°, 10°, and 20°. At each removal, bunches were examined and freshened to bring appearance as close as possible to excellent. The amount of necessary trim was recorded and bunches were either left naked or wrapped in perforated (4- to 0.5-cm holes) polyethylene bags. Polyethylene bagged bunches were prepared from the waxed cartons and from lined and nonlined crates. Naked bunches were prepared only from lined and nonlined crates. Thus we tested the residual effect of container type and icing on shelf life of parsley within two consumer bunch wraps held at three temperatures.

Parsley packaged at the start of the test in polyethylene bags held up well for 21 days at 0° C, for 6 days at 10°, and for 2 days at 20°. In naked bunches parsley held up well for 2 days at either 0° or 10° but less than 1 day at 20°.

After 2 weeks' storage at 0° C, the parsley in waxed cartons was fully salable and required no trim before packaging, whereas parsley in crates was barely salable and required an average of 10 percent trim to freshen its appearance to excellent. Parsley then packaged in polyethylene bags held up well and remained salable for 3 to 8 days at 0°, for 2 days at 10°, and less than 1 day at 20°. In naked bunches, parsley held up well for 2 days at 0° or 10° and for 1 day at 20°.

After 4 weeks' storage at 0° C, none of the storage containers of parsley was fully salable, but 40 percent trim brought general appearance rating to excellent. No difference in parsley in the various containers was readily apparent. Following packaging in polyethylene bags, parsley held up well and remained salable for up to 21 days at 0°, 4 days at 10°, and 1 to 2 days at 20°, with bunches packaged from waxed cartons holding up somewhat better than those from wirebound wood crates. Parsley in naked bunches held up well for 3 days at 0°, 2 days at 10°, and 1 day or less at 20°.

After 8 weeks' storage at 0° C, parsley in storage containers was less desirable than after 4 weeks' storage and required 70 percent trim to bring general appearance to a rating of excellent. Following packaging in polyethylene bags, parsley held up well at 0° for 14 days in bunches packaged from waxed cartons, 7 days in bunches packaged from iced lined or nonlined crates, and 2 to 3 days in bunches packaged from dry crates. At 10°, parsley from waxed cartons held up well for 2 to 3 days and from crates for 1 to 2 days. At 20°, all polyethylene-packaged parsley held up well for only 1 day. Parsley in naked bunches held up well at 0° for 1 to 4 days, at 10° for 1 day or less, and at 20° for less than 1 day.

In general, consumer-unit packages of parsley held up well for significantly longer at 0° C than at either 10° or 20° (table 8). Parsley previously stored in containers with container and top ice held up significantly longer at 0° than parsley from dry (noniced) storage, but at 10° and 20° differences

Table 8.--Shelf life as days salable of parsley consumer-packaged in various containers after 2, 4, and 8 weeks' storage dry or with container and top ice at 0° C and held at 0°, 10°, and 20°[1/]

Consumer bunch wrap and storage container	Shelf life[2/] at indicated holding temperature (C) and previous storage icing						Average
	0°		10°		20°		
	Dry	Iced	Dry	Iced	Dry	Iced	
	Days	Days	Days	Days	Days	Days	Days
Polyethylene:							
Waxed carton----	12.8	13.0	2.2	3.0	0.7	1.0	5.5 a
Lined crate-----	3.2	12.8	1.8	2.0	.7	1.0	3.6 a
Nonlined crate--	10.5	11.0	1.8	1.8	.8	1.0	5.0 a
Naked:							
Lined crate-----	2.7	3.0	1.3	1.7	.7	.7	1.7 b
Nonlined crate--	1.8	3.0	1.3	1.8	.7	.7	1.5 b
Temperature X icing average---	6.2 b	8.6 a	1.7 c	2.1 c	0.7 c	0.9 c	---
Temperature average---------	7.38 a		1.87 b		0.80 b		---

Consumer bunch wrap	Shelf life[3/] at holding temperature (C) of--			Average
	0°	10°	20°	
	Days	Days	Days	Days
Polyethylene------	9.4	2.6	0.9	4.3 a
Naked-------------	2.1	1.5	.5	1.6 b
Average------	6.0 a	2.1 b	.7 b	---

1/ Relative humidity was 95 percent at 0° and 10° and 60 percent at 20°. Duncan's multiple range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (8).

2/ Each simple value is based on observations of 6 bunches of parsley.

3/ Each simple value is based on observations of 24 bunches of parsley with only data for parsley from crates included.

were not significant. Parsley packaged in polyethylene bags held up significantly longer than parsley in naked bunches owing mainly to control of weight loss and wilt (tables 9, 10). Of the three storage container types, the waxed carton held parsley best in salable condition, but differences in shelf life were not statistically significant (table 8).

Test 4.--Parsley held in air at 0°, 5°, 10°, 15°, 20°, and 25° C after packaging in consumer-unit polyethylene bags following 4 and 8 weeks' storage with container and top ice at 0°

In similar tests but using six crates of parsley, much the same results were obtained as in test 3. Two crates each of parsley on August 29, September 6, and September 12 were purchased at a Washington, D.C., wholesale market. On arrival at Beltsville, sample bunches from each of the six crates were freshened by trimming and either packaged in perforated polyethylene bags or left naked before placing at 0°, 10°, or 20° C in air for shelf-life tests. The crates with the remainder of the parsley bunches were placed at 0° with container and top ice for subsequent shelf-life testing after 4 weeks and 8 weeks. After 4 and 8 weeks, sample bunches for shelf-life testing were held naked or in polyethylene consumer bags at 0°, 5°, 10°, 15°, 20°, and 25°.

Parsley in crates was fully salable at start of the tests and after 4 weeks with container and top ice at 0° C, but appearance was benefited by about 5 percent trimming. After 8 weeks' storage, parsley in crates was not salable, but it was made salable by washing and trimming 55 percent by weight.

Holding times at 5°, 15°, and 25° C were generally shorter than at 0°, 10°, and 20°, respectively, for parsley held in polyethylene bags but were about the same when held naked (table 11). Here the deleterious effect of low humidity on the naked parsley apparently masked the temperature effect.

In general, consumer units of parsley held up significantly longer in polyethylene bags than in naked bunches and at lower temperatures with high relative humidity than at high temperatures with low relative humidity. Also, consumer-packaged parsley held up longer before and after 4 weeks' storage than after 8 weeks' storage.

DISCUSSION AND CONCLUSIONS

The storage and shelf life of fresh green watercress, parsley, and mint can be maintained by proper handling, packaging, and refrigeration. For best quality maintenance these greens should be kept at 0° C and 95 percent relative humidity or above throughout storage and marketing. During transit and storage they may be protected from moisture loss, temperature rise, and accompanying deterioration by using crushed top ice within and around the shipping and storage crates. During retailing and home storage, they need the protection afforded by packaging in moisture-retentive film and by refrigeration.

Unprotected watercress, parsley, and mint exposed to low relative humidity lost weight rapidly and such losses associated with various wilt symptoms were higher than expected. Thus when moderate or commercially significant symptoms were seen, an average of about 40 percent weight had been lost from

Table 9.--Weight loss from parsley during 3 days' holding at various temperatures and relative humidities when consumer-packaged in naked bunches or polyethylene bags before and after storage in crates at 0° C with container and top ice[1/]

Temperature (C) and relative humidity (percent) when held in--	Daily weight loss when consumer-packaged at indicated storage time			
	Before	After 2 weeks	After 4 weeks	After 8 weeks
	Percent	Percent	Percent	Percent
Naked bunches:				
0° and 95	8.4	9.1	9.9	10.9
10° and 95	6.5	8.5	12.3	18.1
20° and 60	11.4	17.6	22.5	26.7
Polyethylene bags:				
0° and 95	.5	.7	.7	.9
10° and 95	1.1	.6	1.7	1.4
20° and 60	1.7	2.1	2.7	2.6

1/ Each value is based on 4 bunches of parsley.

Table 10.--Wilt-turgor rating of parsley after 1-3 days' holding at various temperatures and relative humidities when consumer-packaged in naked bunches before and after storage in crates at 0° C with container and top ice[1/]

Temperature (C) and relative humidity (percent) after holding--	Wilt-turgor rating when packaged in naked bunches at indicated storage time			
	Before	After 2 weeks	After 4 weeks	After 8 weeks
1 day:				
0° and 95	8.5	8.0	7.5	9.0
10° and 95	9.0	9.5	8.0	7.2
20° and 60	7.8	4.0	5.0	2.0
2 days:				
0° and 95	5.5	6.0	6.8	7.8
10° and 95	5.8	8.5	6.1	3.5
20° and 60	5.5	2.5	3.0	.5
3 days:				
0° and 95	4.0	3.0	4.8	6.5
10° and 95	4.0	4.2	4.0	2.0
20° and 60	4.5	2.0	2.2	0

1/ Each value is based on 4 bunches of parsley. All comparable bunches of parsley, consumer packaged in polyethylene bags, rated 10 at all observations. For description of ratings, see table 5.

Table 11.--Shelf life as days salable of parsley when consumer-packaged in naked bunches or polyethylene bags before and after 4 and 8 weeks' storage in crates with container and top ice at 0° C and subsequently held at various temperatures and relative humidities[1/]

Temperature (C) and relative humidity (percent) when held in--	Shelf life after weeks in storage			Average
	0	4	8	
	Days	Days	Days	Days
Polyethylene bag:				
0° and 95	28.0 b	36.3 a	15.0 c	26.4 a
10° and 95	13.0 c	5.7 d	6.0 d	8.2 b
20° and 60	3.0 d	2.7 d	1.3 d	2.3 c
Average	14.7 a	14.9 a	7.4 b	--- 12.3a
Naked:				
0° and 95	1.7 d	1.3 d	1.7 d	1.6 c
10° and 95	1.7 d	1.3 d	1.7 d	1.6 c
20° and 60	1.0 d	1.0 d	.3 d	.8 c
Average	1.5 c	1.2 c	1.2 c	--- 1.3 b
Grand average	8.1 a	8.0 a	4.3 b	---
Polyethylene bag:				
0° and 95	28.0 b	36.3 a	15.0 c	
5° and 95	---	10.7 cd	6.7 de	
10° and 95	13.0 c	5.7 de	6.0 de	
15° and 75	---	1.7 e	1.7 e	
20° and 60	3.0 e	2.7 e	1.3 e	
25° and 40	---	1.3 e	.7 e	
Naked:				
0° and 95	1.7 e	1.3 e	1.7 e	
5° and 95	---	1.3 e	1.7 e	
10° and 95	1.7 e	1.3 e	1.7 e	
15° and 75	---	1.3 e	2.7 e	
20° and 60	1.0 e	1.0 e	.3 e	
25° and 40	---	1.0 e	.3 e	

1/ Each simple value is based on observations of 3 bunches of parsley. Duncan's multiple range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (8).

each of the three greens. This could be a significant monetary loss in produce sold by weight as well as a loss in food value since weight loss and wilt have been associated with vitamin loss from leafy greens. Packaging these greens in perforated moisture-retentive polyethylene bags can prevent wilting and vitamin loss by greatly reducing weight loss.

At 25° C, parsley respires and produces heat at about 83 megajoules per metric ton per day, or about 10 times the rate at 0°. Differences for watercress and mint are even more striking. These differences in respiration rates partly explain why watercress, parsley, and mint deteriorate much faster at higher temperatures than at 0°

The appearance of watercress, parsley, and mint in supermarkets leaves much to be desired. Ratings for parsley ranged from excellent to very poor. With more attention given to improved packaging and refrigeration, more greens offered for sale would be in excellent condition.

Reduced ascorbic acid (vitamin C) content was measured in watercress, parsley, and mint on arrival in Beltsville. Vitamin changes during storage were only measured for parsley. From a start averaging 91 mg per 100 grams of fresh weight, reduced ascorbic acid in parsley dropped to 62 and 31 mg in 4 and 8 weeks' storage, respectively. During holding tests, parsley lost ascorbic acid more rapidly at higher than at lower temperatures and in naked than in polyethyelene-protected bunches. Thus proper packaging and refrigeration could better conserve this important nutrient within the leafy greens until they are prepared and eaten.

In preliminary holding tests, the bunches of watercress and mint remained salable for 4 weeks in polyethylene bags at 0° C and 95 percent relative humidity but only 4 days in naked bunches, whereas at 15° and 75 percent relative humidity they remained acceptable for 2 to 4 days in polyethylene bags and 1 day or less in naked bunches. At 25° and 40 percent relative humidity they held up well for only 1 to 4 days in polyethylene bags and for less than 1 day in naked bunches. Waxed cartons of watercress and mint and wood baskets of parsley were maintained in excellent condition for 2 weeks at 0° under package and top ice with some salvageable after 3 or 4 weeks. Thus watercress could be held longer than the reported 3 or 4 days and 3 to 4 months might be too long to expect to store parsley. Mint held up about as well as watercress and parsley.

In storage and shelf-life tests, some of the treatments during storage affected subsequent shelf life of parsley, which was consumer-packaged on removal from storage containers. However, holding conditions during shelf life had much more effect on length of shelf life than prior storage conditions did. Storage container and film liner had no significant effect on shelf life. But consumer-packaged parsley with container and top ice remained salable significantly longer than parsley from containers stored dry without ice. Holding parsley bunches in polyethylene bags provided significantly longer shelf life than holding the bunches naked. Shelf life at 0° C was much longer than at 5° to 25°. Storage time significantly affected subsequent shelf life. Shelf life averaged 8 days after 0 and 4 weeks' storage compared with 4 days after 8 weeks. But storage effect on parsley shelf life was overshadowed by the effects of consumer-package type and shelf-life temperature. Thus shelf

life averaged 12 days in polyethylene bags and 1 day in naked bunches. In polyethylene bags, shelf life averaged 26 days at 0°, 8 days at 10°, and 2 days at 20°.

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